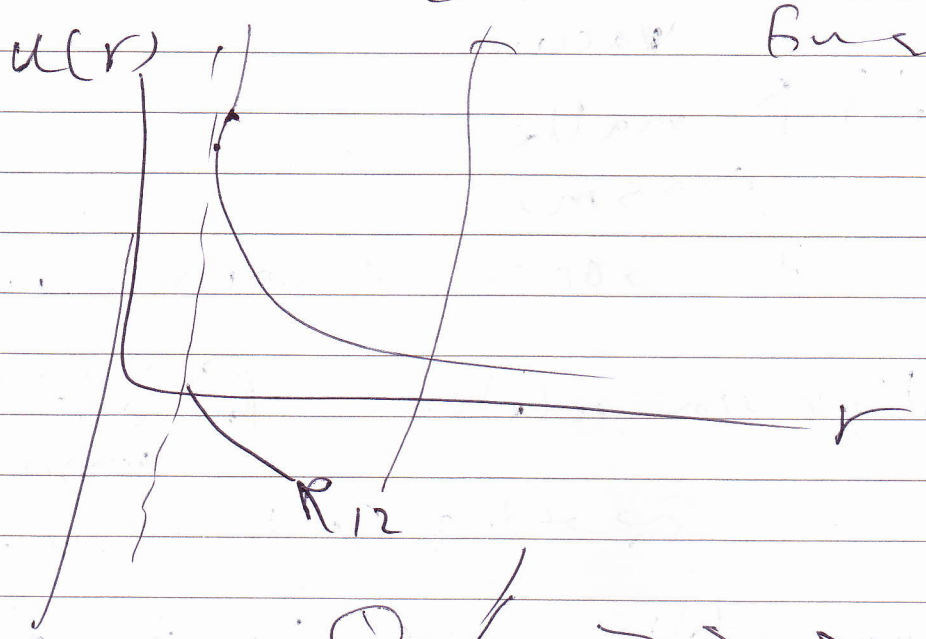
كوسفاليف

$$u \xleftarrow{z_1 z_2 e^2} r$$

nuclear force



① $L >> \lambda_D$ ← الطول الموجي

طول ديباي لغوص عند الشحنة

② $\omega_{pe} > \nu_{ei}$ → collision frequency

③ $\lambda_D^3 >> 1$

Dielectric media البلازما

شوكت تحرك الضوء

الفرق بين vacuum و البلازما

vacuum
matter
plasma

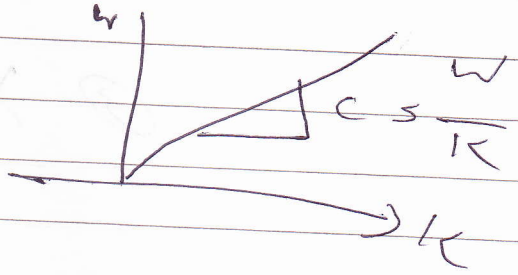
Linear dispersion relation of electromagnetic wave is strongly modified from in vacuum

$\omega = K c$ in vacuum

$c = \frac{\omega}{K}$

wave number

dispersion relation in vacuum



ظاهرة سفر علامة التنزع

التاريخ / / ٢٠٠ / / الموضوع :

2 phonement

① ~~group~~

. C phase velosity
② group velocity

in vacuum

The phase velosity ϑ_ϕ of EM wave

$$C = \frac{\omega}{K} = \frac{1}{\sqrt{\mu_0 \epsilon_0}}$$

in matter

$$V_\phi = \frac{\omega}{K} = \frac{1}{\sqrt{\mu \epsilon}}$$

in plasma

$$\mu = \mu_0$$

$$\epsilon \neq \epsilon_0$$

we can define ϵ in plasma by this equation

$$\epsilon(\omega) = \epsilon_0\left(1 - \frac{\omega_p^2}{\omega^2}\right)$$

drive

هذا المعادلة نعرف مدى تشتت او تشاكل او تكامل

drive th disper relation of EM wave in plasma

$$v_\phi = \frac{\omega}{k} = \frac{1}{\sqrt{\mu\epsilon}} = \frac{1}{\sqrt{\mu}\sqrt{\epsilon}} \quad \cdots (1)$$

(where $\mu = \mu_0$ in plasma)

$$\frac{\omega}{k} = \frac{1}{\sqrt{\mu_0}\sqrt{\epsilon}}$$

$$\epsilon = \epsilon_0 \left(1 - \omega_p^2/\omega^2\right)$$

$$\sqrt{\epsilon} = \sqrt{\epsilon_0 \left(1 - \omega_p^2/\omega^2\right)} \quad \text{---} \quad (2)$$

نعوض (1) في (2)

$$\frac{\omega}{k} = \frac{1}{n} \propto \frac{1}{\sqrt{\epsilon_0 \left(1 - \omega_p^2/\omega^2\right)}}$$

$$\frac{\omega}{k} = \frac{1}{\sqrt{\mu_0}} \propto \frac{1}{\sqrt{\epsilon_0}} \propto \frac{1}{\sqrt{1 - \omega_p^2/\omega^2}}$$

$$\omega^2 = k^2 c^2 + \omega_p^2$$

الموضوع :

التاريخ / / ٢٠٠

$$\frac{\omega}{k} = \frac{1}{\sqrt{\mu_0 \epsilon_0}} \propto \frac{1}{\sqrt{1 - \omega_p^2/\omega^2}}$$

$$\frac{\omega}{k} = \frac{c}{\sqrt{1 - \omega_p^2/\omega^2}}$$

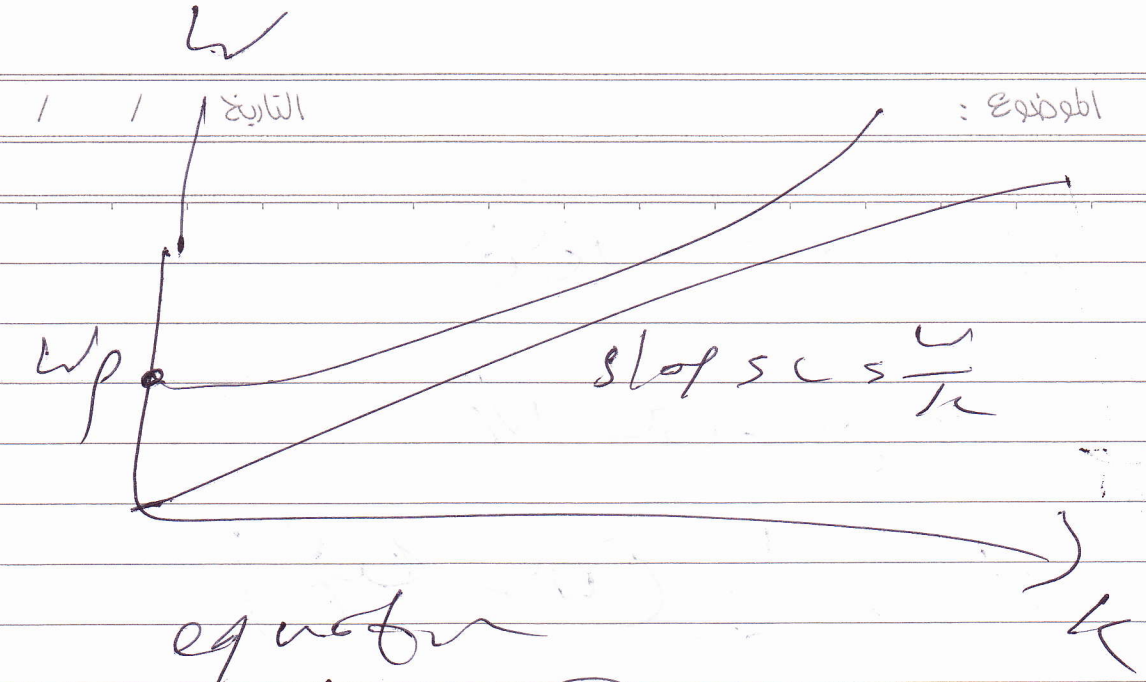
$$\frac{\omega^2}{k^2} = \frac{c^2}{1 - \omega_p^2/\omega^2}$$

$$k^2 c^2 = \omega^2 - \omega^2 \cdot \frac{\omega_p^2}{\omega^2}$$

$$k^2 c^2 = \omega^2 - \omega_p^2$$

the dispersion relation of EM wave is plasma is

$$\omega^2 = k^2 c^2 + \omega_p^2$$



equation A we get

$$\omega = \sqrt{\omega_p^2 + k^2 c^2}$$

if $kc \gg \omega_p$

$$\omega \cong kc$$

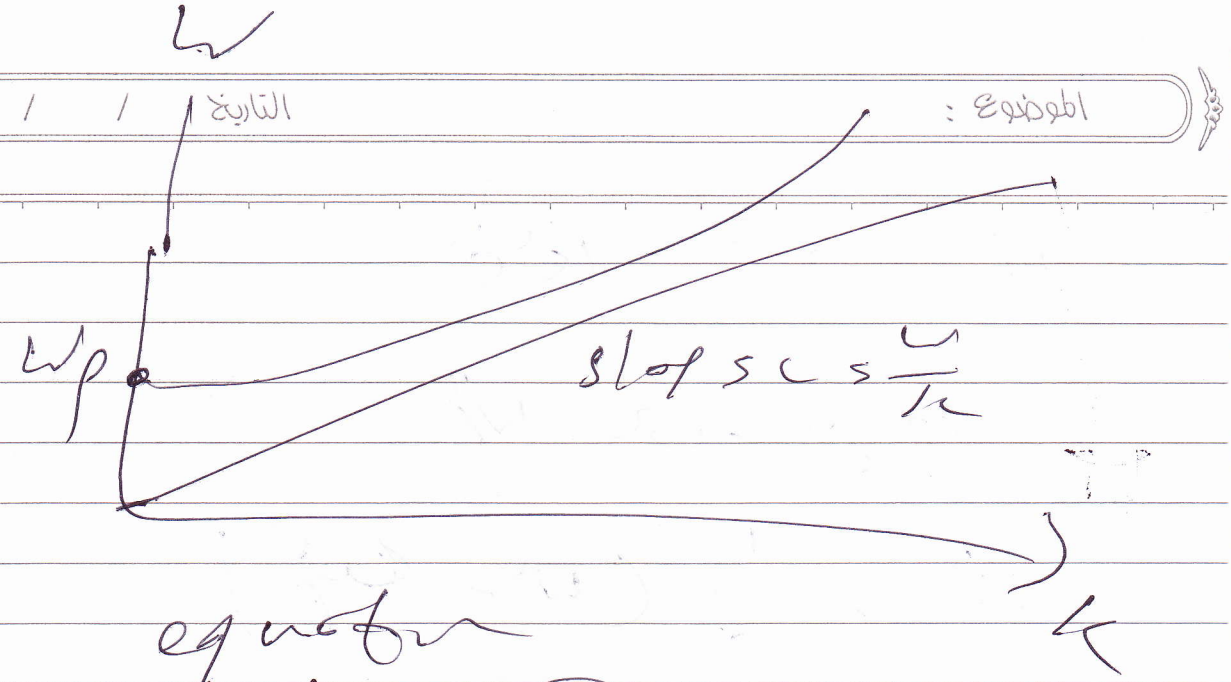
let a plane wave

propagation direction

$$\vec{E} = \vec{E}_0 e^{i(kz - \omega t)}$$

Phase velocity

from dispersion relation



equation A we get

$$\omega = \sqrt{\omega_p^2 + k^2 c^2}$$

if $k c \gg \omega_p$

$$\omega \cong k c$$

let a plane wave propagation direction

$$\vec{E} = \vec{E_0} e^{i(kz - \omega t)}$$

Polarization

From dispersion relation

$$\omega^2 = \omega^2 + k^2c^2$$

$$k^2c^2 = \omega^2 - \omega_p^2$$

$$k^2 = \frac{1}{c^2}(\omega^2 - \omega_p^2)$$

$$k = \frac{1}{c}\sqrt{\omega^2 - \omega_p^2}$$

---

if $\omega > \omega_p$

real ⇒ k ق

~~if~~ ∴ k is real

real

~~this is~~

the wave propagats in plasma without decay

can explain

معادلة انتشار الموجات

$$k^2 = \frac{1}{c}\sqrt{\omega^2 - \omega_p^2}$$

$\omega < \omega_p$

حيث $k^2 < 0$

$$k = \frac{1}{c}\sqrt{-\omega_p^2 + \omega^2}$$

$$= \frac{1}{c}\sqrt{-(\omega_p^2 - \omega^2)}$$

$$k = \frac{1}{c}\sqrt{i^2(\omega_p^2 - \omega^2)}$$

$$k = \frac{1}{c} i \sqrt{\omega_p^2 - \omega^2}$$

$$k = i\left[\frac{1}{c}\sqrt{\omega_p^2 - \omega^2}\right]$$

$K = i|K|$ this is imagenary

Z.W

التاريخ / / ٢٠٠

الموضوع :

$$\vec{E} = E_0 e^{i(kz - \omega t)}$$

$$E = E_0 \left(e^{ikz} e^{-i\omega t} \right)$$

$$k = \pm i|k|$$

$$E = E_0 \left(e^{\pm i|k|z} e^{-i\omega t} \right)$$

$$E = E_0 \left(e^{-|k|z} \times e^{i\omega t} \right)$$

الحل المطلوب

wave is decay in z-direction and will be reflected

Z.W

لا يوجد أسرع من سرعة الضوء — استنتاج

notes according to Einsteins relativity nothing should propagate1 faster than the light speed.

~~is plasma?~~

in plasma the phase velocity is

$$W_\phi = \frac{c}{\sqrt{1 - \frac{w_p^2}{w^2}}} > c$$

group velocity
plase velocity

يعني السرعة الطورية

in vacuum

$V_g = c = V_\phi$ phase velocity

group velocity

in plasma

in general $V_g = \frac{d\omega}{dk}$

in plasma $V_g = c\sqrt{1 - \frac{\omega_p^2}{\omega^2}} < c$

recall

$$V_\phi = \frac{\omega}{k} = \frac{c}{\sqrt{1 - \omega_p^2/\omega^2}}$$

① $\omega < \omega_p$ ⟶ evanescent تلاشي

هنا الموجة تنزل / تتضاءل في الـ plasma

this is emegeneng and this wave is evanescent

تسمى الموجة المتلاشية

$\omega < \omega_p$

propagation تنتشر وتمتص

skin depth في البلازما

if $\omega << \omega_p$

$$\therefore k = \frac{1}{c}\sqrt{\omega^2 - \omega_p^2}$$

$$k = \frac{1}{c}\sqrt{-\omega_p^2}$$

$$= \frac{1}{c}\sqrt{i^2 \omega_p^2}$$

$$k = \frac{1}{c} i\omega_p$$

$$k = i\frac{\omega_p}{c}$$

$$k = i\frac{1}{\delta}$$

δ is skin depth in plasma

Deby Shielding

th positive charge in plasme will attractive the electron and repel th ions, making a cloud of net negative charge around it reducing (shielding) the electro

in vacuum $\phi = \frac{q}{r}$

in plasma $\phi = \frac{q}{r} e^{-r/\lambda_D}$

note) if $r \gg \lambda_D$

the influence of th positive charge is negligible

this is called Debye shielding

where $\lambda_D = \left(\frac{K_B T}{4\pi n e^2} \right)^{1/2}$

$\mathcal{R}$ — ohm

ϵ_0 — $\frac{1}{4\pi 9}$

μ_0 — $\frac{4\pi}{c^2}$

B — $\frac{B}{c}$

$$c = \frac{1}{\sqrt{\mu_0 \epsilon_0}}$$

$$c = \sqrt{\frac{4\pi}{c^2} \cdot \frac{1}{4\pi}}$$

$$c = \frac{1}{\sqrt{\frac{1}{c^2}}}$$ = speed of light in vacuum

in plasmas, are often given ten

$$T(ev) = K_B T(K)$$

$$T(K) = \frac{T(eV)}{K_B} = \frac{1.6 * 10^{-19}}{1.38 * 10^{-23}\ J/K}$$

$$= 11600\ K$$

ϵ_0 dielectric constant.

μ_0 magnetic permeability

(A)

$\nabla \times B = \mu_0 j$ ... Ampers law

take the divergence of the equation we get

$\nabla \cdot (\nabla \times B) = \mu_0 \nabla \cdot j$ ~~static~~

for static $= 0$

because the divergent of curl is zero

~~Conservation~~

conservation of charge in time - dependent, we get

$$\nabla \cdot \vec{J} = \frac{-\partial \rho}{\partial t} \Rightarrow \nabla \cdot \vec{J} + \frac{\partial \rho}{\partial t} = 0$$

و poisons equation

$$\nabla \cdot \vec{E} = \frac{\rho}{\epsilon_0}$$

$$\rho = \epsilon_0 (\nabla \cdot E)$$

$$\nabla \cdot \vec{J} + \frac{\partial}{\partial t} (\nabla \cdot E) = \nabla \cdot \left(J + \epsilon_0 \frac{\partial E}{\partial t} \right)$$

(B) (A)

for equation A and B we get

$$\nabla \times B = \mu_0 \left(J + \epsilon_0 \frac{\partial E}{\partial t} \right) = \mu_0 J + \mu_0 \epsilon_0 \frac{\partial E}{\partial t}$$

نأخذ تفاضل بالنسبة للزمن

Maxwell displacement current

Z.W

القوة المؤثرة

قوة لورنتز

$$f = Eq + qv \times B$$

قوة لورنتز تنتج عن شحنة e بسبب تسارع الجسيم المشحون تعطى بتعجيل acceleration

$$f = f_m + f_e = \cancel{Eq} = ma = q(v \times B + E)$$

$$a = \frac{q}{m}(v \times B + E)$$

$$\frac{dv}{dt} = \frac{q}{m}(v \times B + E)$$

Lorentz

$$\nabla \times B = \mu(J + \varepsilon_0 \frac{\partial E}{\partial t})$$

$$\begin{cases} \rho = 0 \\ J = 0 \end{cases} \Rightarrow \boxed{\nabla \times B = \mu_0 \varepsilon_0 \frac{\partial E}{\partial t}}$$

current density

كثافة التيار

معادلة الموجة

$$c = \frac{1}{\sqrt{\mu_0 \varepsilon_0}} \quad / \quad c^2 = \frac{1}{\mu_0 \varepsilon_0}$$

انه التغير في المجال الكهربائي

يعني

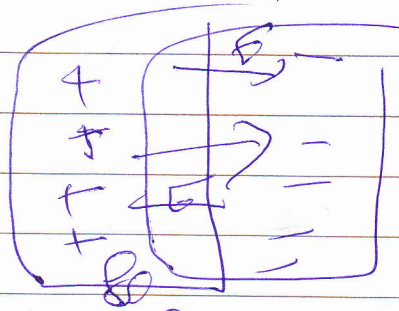
Meaning changing B-field induce an electric field, but also a changing E-field induce B-field

we can calculate the group velocity plasma frequency

تردد البلازما يعرف بالتردد الكهربائي

electron plasma frequency

(plasma fre. ω_p)



تتحرك الإلكترونات السالبة نحو الأنود الموجب تاركة وراءها أيونات موجبة تسبب تأثير حاجز كهربائي يعيق حركة الإلكترونات

let L is the thickness of the plasma.

E is the electric field between the partical

Force تولد

$$E = \frac{F}{q}$$

by Possions equation

$$\frac{\partial G}{\partial x} = 4\pi\rho$$

$$E = 4\pi n e \delta$$

the charge per unit area is $(-neL)$, and the force per unit area is the electric field times the charge per unit area)

$$F = (-neL) * (4\pi ne\delta)$$

$$F = m\ddot{\delta} = -4\pi n^2 e^2 \delta L$$

$$\vec{F} = -e\vec{E}$$

$$F = -4\pi n e^2 \delta = m\ddot{\delta}$$

$$m_e\ddot{\delta} + 4\pi n e^2 \delta = 0$$

$$\ddot{\delta} + \frac{4\pi n e^2}{m}\delta = 0$$

prove that?

similar this ~~#~~ is the equation of harmonic oscillation with frequency

$$\omega_{pe} = \left(\frac{4\pi n e^2}{m}\right)$$

(electron Plasma frequency)